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(54) **HIGH PRESSURE VORTEX INJECTOR.**

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Description

BACKGROUND AND SUMMARY OF THE INVENTION

In order to shorten the time to vaporize fuel in a cylinder of an engine it is desirable to introduce fuel having a very fine particle size. In addition, to reduce the levels of emissions in an engine, especially a two cycle engine, it is desirous to inject fuel directly into the cylinder. United States Patent 2,981,483 illustrates a low pressure fuel injector having a screw thread-like portion proximate its end. As the fuel flows through the helix of the thread it is rotated. The use of such a means to rotate or swirl the fuel does not yield a finely atomized spray and further such type of mechanism is expensive to manufacture. GB-A-2 090 328 illustrates another fuel injector having a housing which includes a plurality of orifices spaced about a metering orifice. The combination thereof provides for a swirling and turbulent action of the fuel that enters the housing between the needle valve and the metering orifice. United States patent 4,186,883 illustrates another low pressure electromagnetic fuel injector comprising a metering orifice located downstream of a remotely situated valve seat and a movable ball valve which selectively seats upon various surfaces of the valve seat. A plurality of passages are located between the valve seat and the metering orifice and situated to impart a radial component to the fuel flow. A high pressure vortex injector according to the preamble of claim 1 is known from FR-A-1 535 190.

Reference is made to our copending application WO 88/03226, Application No. 87 907 560.4.

It is an object of the present invention to inject fuel directly into a cylinder of an engine in a defined swirl or vortex pattern. Another object of the invention is to provide an injector that can inject fuel in a fully filled or partially filled conical swirl pattern. It is yet another object of the invention to provide an injector having a vortex chamber and to continually circulate fuel therein when the injector is closed to enhance the rapid formation of the conical swirl pattern. Still another object of the invention is to provide an injector capable of injecting a variety of different types of fuels, i.e., gas, oil, kerosene etc.

Accordingly, the invention comprises:

A high pressure vortex fuel injector comprising a hollow housing or body including a plurality of passages at least one of which is adapted to receive fuel through an inlet. A valve seat is secured to the housing and includes a metering orifice and a first conically shaped surface disposed directly upstream of the metering orifice. The injector also includes means for guiding the piston into seating

relationship with the valve seat to control the flow of fuel through the metering orifice and means for moving the piston relative to the valve seat. The injector further includes means upstream of the metering orifice for forming a swirl or vortex chamber in cooperation with the first conically shaped surface. More particularly, a second conically shaped surface is fixedly spaced from the first conically shaped surface and conformal therewith forming a fixedly spaced swirl chamber there between. A plurality of straight passages extends through the piston guide and the second conically shaped surface and are oriented at oblique angles relative to the first conically shaped, such that fuel exiting these straight passages directly impacts the first conically shaped surface generally tangentially and is caused to flow within the swirl chamber in a downward spiral manner towards the metering orifice.

Many other objects and purposes of the invention will be clear from the following detailed description of the drawings.

Brief Description of the Drawings

In the drawings:

FIGURE 1 is a cross-sectional view of a fuel injector and illustrates a number of embodiments of the present invention.

FIGURES 2 and 3 are plan views of various portions of a bobbin.

FIGURE 4a is a plan view of an insert taken through section 4-4 of FIGURE 1 illustrating passages within an insert.

FIGURE 5a is a cross-sectional view of the insert taken through section 5-5 of FIGURE 4.

FIGURE 4b and 5b illustrate an alternate embodiment of the insert.

FIGURE 6 illustrates an isolated plan view of an end cap.

FIGURE 7 is another alternate embodiment of the invention.

Detailed Description of the Drawings

FIGURE 1 illustrates a high pressure vortex injector 8 capable of fully atomizing and injecting fuel directly into a cylinder 202 of an engine generally shown as 204 in a full, conical spray pattern. As will be seen below, subject to various minor modifications to the structure and method of control, the injector can also generate a hollow conical spray pattern. FIGURE 1 shows three embodiments of the invention, i.e. the preferred embodiment and two alternate embodiments. These alternate embodiments are directed to additional fuel carrying passages which communicate various parts of the injector to a drain and are more fully described

below. The fuel injector 8 includes a housing 10 comprising of an upper bore 12 and a first passage 14 in communication therewith. An annular land 16 is situated proximate the bottom of the upper bore 12 about one end 18 of the passage 14. The upper bore 12 further includes an annular recess 20 formed at the bottom thereof about the land 16. The housing 10 further includes a stepped bore 30 situated at a second or other end 22 of the first passage 14. The stepped bore 30 includes a first and a second shoulder 32 and 34 respectively. A plurality of angled fluid passages 36a-e communicate the annular recess 20 with the upper extreme of the stepped bore 30. In the preferred embodiment of the invention, five such passages are used, it being understood that the number, size and angle of these passages 32 will vary with the specific application of the invention. A fuel inlet 38 is provided in the housing 10 to receive fuel and to communicate same to the upper bore 12 from a high pressure pump 40.

Positioned within the upper bore 12 is a solenoid assembly 50. The solenoid assembly 50 includes a bobbin 52 which comprises a hollow cylindrical member 54, an upper end 58a and a lower end 58b radially extending therefrom. An electric coil 60 is wound about the member 54 and is adapted to receive control signals generated by an ECU 55 through a plurality of terminals 62a and b. Typically the ECU will generate pulsed control signals. By varying the pulse width or duty cycle of these signals the conical spray pattern may vary such as from a fully filled pattern to a partially filled or hollow pattern. The second or lower end 58d of bobbin is adapted to be tightly received within the upper bore 12. The upper or first end 58a, as well as the exterior diameter of the electric coil 60, are of a smaller diameter than the diameter of the upper bore 12 to provide an annulus 64 between the solenoid assembly 50 and the upper bore to permit fuel to surround the electric coil 60 thereby cooling same.

A metal stator 70 is received within the bobbin 52 and includes a top end 72 extending above the upper end 58a. The top end 72 of the stator 70 is received within a blind bore 66 of an end cap 68. The cap 68, in turn, is received on a narrow shoulder 69 of the housing 10. This narrow shoulder in concert with the cap 68 provides a preferred reluctance path for magnetic flux and forms part of the magnetic circuit and provides for a hard metal contact therebetween. It can be shown that by using such a construction, upon activation of the coil 60, the stator 70 is desirably magnetically saturated. The housing and cap may be fabricated of steel such as 430 FR. The securement of the stator 70 to the bobbin is more clearly shown by reference to FIGURES 2 and 3.

FIGURES 2 and 3 show isolated plan views of the upper end 58a and lower end 58b respectively. In addition, for the purpose of illustration, the stator 70 is also shown. FIGURES 2 and 3 illustrate the outer surface of the member 54, shown in dotted line, about which the coil 60 is wound. The inner surface of the member 54 includes a plurality of radially directed ribs 210a, b and c. The ends 212 of the ribs 210 are arcuately shaped to receive and secure the stator 70 to the bobbin 52. The rib 210c is shown in FIGURE 1 and appears as a thickened portion of the left hand wall of the member 54. With the stator 70 positioned within the bobbin 52, the stator 70, the interior wall of the member 54 and ribs 210 form a plurality of flow passages 56 a, b and c. Passage 56b is illustrated in FIGURE 1.

The solenoid assembly 50 further includes an armature assembly 74 comprising a low mass armature 76 which is loosely received within the first passage 14 and partially extends into the center of the bobbin 52 thereby improving the magnetic circuit formed between an interior portion 75 of the housing 10 and solenoid assembly. An upper end 77 of the armature 76 is spaced from the stator 70 thereby defining a working air gap 79. This gap 79 may typically be .0038 inches (.097mm). The armature 76 and stator 70 may be of a highly magnetically permeable material such as silicon iron (Si Fe) and plated with a thin layer (.002 in., .05mm) of electrolytic nickel or chrome to provide a hard, corrosion resistant, non-magnetic surface. The armature 76 includes a necked-down or narrow portion 78 for reducing the mass thereof. A rod or piston 80 extends from the armature 76. The rod 80 includes a first end 82 which preferably terminates in a spherically shaped valve 84. A second end 86 of the rod 80 may be press fit within a bore 88 of the armature 76. A spring 90 is positioned about the armature 76 and is located between a flanged end 92 thereof and the first shoulder 32 of the housing thereby urging the armature 76 outwardly relative to the stator 70.

The injector 8 further includes an insert 100 comprising an axially extending cylindrical wall 102 open at one end 104. As can be seen from FIGURE 1 the insert 100 forms a substantially cup-like member which in concert with the housing 10 forms a fuel receiving chamber 116 in communication with the fluid passages 36a-e. Such chamber 116 provides a fuel reservoir or chamber for the pressurized fuel. The cylindrical wall 102 is tightly received within the stepped bore 30 and the open end 104 is forceably lodged against the second or larger diameter shoulder 34 of the housing 10. The insert 100 further includes a bottom element 106 integrally formed with the cylindrical wall 102 opposite the open end 104. The insert 100 includes a third passage 108 for guiding and for slidably re-

ceiving the rod or piston 80. The bottom element 106 forms a upper surface 110, interior to the stepped bore 30, and a generally concave protrusion 112 extending axially as part of a lower surface 114. The insert 100 further includes a plurality of non-intersecting fluid passages 120 a, b, and c which are more clearly as shown in FIGURES 4a, 4b, 5a and 5b.

The injector 8 further includes a valve seat 130 positioned below the bottom element 106 comprising a surface 132 which is spaced from and which is preferably conformal to the protrusion 112. In the embodiment illustrated in FIGURE 1 the protrusion 112 is conical and the surface 132 is also preferably conically shaped. The valve seat 130 further includes a metering orifice 134 preferably located at the nadir of the surface 132. The insert 100 and valve seat 130 are secured within the housing 10 by an end cap 128. As illustrated in FIGURE 1 the end cap 128 is threadably received onto the housing 10; however, such securement may be obtained by many equivalent known means. It can be appreciated that the end cap 128 can be fabricated as an integral portion of the housing 10. As illustrated in FIGURE 1 the injector 8 is loosely received within the cylinder 202 forming a narrow annulus 206 therebetween. After extended periods of operation carbon and other particulates will tend to accumulate in the annulus 206. If substantial amounts of carbon is deposited it makes removal of the injector 8 difficult if not impossible. It has been found that if the lower portion of the housing 10 such as the end cap 128 portion is coated with a polymer, such as a polymer in the family including polyimide, Mylar and Teflon the injector can be easily withdrawn.

The conically shaped space formed between the valve seat 130 and the projection 112 defines a swirl or vortex chamber 136 for receiving fuel relatively tangentially from the plurality of passages 120a-c and assists in swirling and rotationally accelerating same prior to ejection through the metering orifice. Typically, the width or thickness of the vortex chamber 136 will be in the range of .003 in. (.076 mm.) to .040 in. (1.016mm.). With reference to FIGURES 4a and 5a the passages 120 extend from the upper surface 110 through to the lower surface 114. Such passages 120 may terminate at enlarged opening 122 proximate the surface 114. The diameter of the passages 120 may vary between .015 inch (.38mm) to .020 inch (.51mm). FIGURE 4a is a plan view of the insert 100 taken in isolation. FIGURE 5a is a cross-sectional view of the insert 100 taken through section 5a-5a of FIGURE 4a and more clearly illustrate the skewed angular orientation of the passages 120. As can be seen of the fluid passages 120a-c is oriented at a predetermined oblique angle relative to the axis

121 of the injector as well as to the surface 132 of the valve seat 130. In the embodiment of the invention shown in FIGURE 1 the protrusion 112 is frusto-conically shaped having a angle of approximately 90° degrees. It is felt that this angle may be varied within the range of 45° degrees to 150° degrees. Correspondingly, the angle of the passages 120 is chosen such that fuel flows radially downward into the swirl chamber 136. As an example, by using a projection 112 having an angle of 90 degrees the orientation of the passages 120 may be at 45 degrees to the axis 121 of the injector. It is not a requirement of the invention that the angle of each of the fluid passages 120a-c relative to the conical projection 112, surface 132 or axis 121 be equal. Further, while the preferred embodiment of the invention illustrates the utilization of a separate insert 100, it can be appreciated that the insert and its various components may be formed as an integral part of the housing 12. In addition, it should be appreciated that the projection 112, surface 132 and swirl chamber 136 need not be formed conically, frusto-conically or formed by constant angle surfaces. As an example the projection 112, surface 132 and swirl chamber 136 may be spherical or alternatively formed by broadly angled surfaces proximate the passage 108 and metering orifice 134 which transition outwardly to a steeper angle.

Reference is briefly made FIGURES 4b and 5b which show an alternate embodiment of the insert 100. The passages 120 have been moved outwardly such that they terminate on a larger radius on the surface 114. The angle of these passages has also been increased to approximately 50 degrees. More specifically, the passages 120 terminate about a radius approximately equal to the radius of the shoulder 133 of the valve seat 130. In this manner fuel exiting the passages 120 flows over the shoulder 133 and is broken up or caused to flow turbulently in the swirl chamber. This added turbulence assists within the atomization of the fuel upon exit from the metering orifice 134.

Reference is again made to FIGURE 1 and more particularly to the top cap 68. The top cap 68 includes a cylindrical cup-shaped element having a bottom 140 and cylindrical walls 142 extending therefrom. The cylindrical walls threadable engage the housing 10 and include a flanged end 144. A surface 146 of the flange end 144 is in contact with an end 147 of the housing and may include a groove 148 for securing an O-ring 150. The bottom 140 includes a plurality of openings 152a, b for receiving the terminals 62a and b. The terminals 62a and b extend through the bottom for securement to the ends of the electrical coils 60. Securement can be achieved by soldering or welding.

The bottom 140 includes the blind bore 66 for

receiving the top end 72 of the stator 70. The bottom 140 further includes a split angular ring 160 extending from the lower side thereof and positioned about of the stator 70 as more clearly shown in FIGURE 6, which is an isolated plan view of the cap 68. The ring 160 properly orients the bobbin.

Upon assembly of the cap 68 to the housing 10, the bottom 140 is positioned apart from the upper end 58a of the bobbin 52 thereby permitting fuel which is received within the annulus 64 to be communicated to the top portion of the bobbin.

As previously mentioned, the bobbin 52 and stator 70 cooperate to form a plurality of a passages 56 to communicate fuel therebetween. The passages 56 are communicated to the fluid passages 36 formed in the housing 10 and further enhance the cooling of the coil 60. Communication with the passages 36 is achieved by forming a plurality of recesses or slots 164 in the lower end 58b of the bobbin as shown in FIGURE 2.

The fuel injector 8 has two operational conditions, one being an open condition and the other a closed condition. FIGURE 1 illustrates the fuel injector 8 in its closed condition wherein fuel is communicated from the inlet 38 to the annulus 64, through the passages 56, the fluid passages 36 and into the fuel chamber 116. Fuel is thereafter communicated through the fluid passages 120 formed within the insert 100 to the vortex chamber 136. The fuel injector is designed to inject fuel directly into the cylinder of an internal combustion. This is accomplished by supplying fuel at a relatively high pressure, such as 1000 - 2000 psi or higher (6900 kpa - 13,8000 kpa). During the closed mode of operation, each of the various fluid carrying passages and chambers is pressurized to the input pressure. Fuel is prohibited from flowing through the metering orifice by virtue of the fact that the rod 80 and valve 84 formed thereon are positioned against a seating surface 135 of the valve seat 130 by the spring 90. When it is desired to enter the open mode of operation an electrical signal such as a pulse width modulated control signal is applied to the electric coil 60 thereby repeatedly urging the armature 76 and rod 80 off from the valve seat 130. As the rod 80 is moved off from the valve seat 130 pressurized fuel within the fuel chamber 116 flows through the fluid passages 120 against the surface 132 of the valve seat 130 thereby initiating a swirled flow. The swirling fluid is accelerated and exits the metering orifice in a spiral conical manner having a predefined exit cone. Simultaneous with the opening of the valve, the high pressure fuel within the fuel chamber 116 flows or, more specifically, leaks between the rod 80 and the third passage 108 and out through the metering orifice, thereby adding an axial component to the fuel flowing therefrom and assisting in

the formation of a fully filled conical spray pattern. The leakage flow passed the rod 80 may be controlled by adding a seal between the insert 100 and the rod 80.

Reference is again made to FIGURE 1 which illustrates alternate embodiments of the invention. One such alternate embodiment adds a outflow passage 170 to the housing 10. This passage 170 communicates the annulus 64 with a drain 172 thereby permitting a constant flow of fuel about the coil thereby further cooling the coil even during conditions when injector is closed. FIGURE 1 also illustrates another embodiment of the invention wherein another outflow passage 176 is provided in the valve seat 130 and cap 128 to communicate the swirl or vortex chamber 136 with the drain 172. In this manner the fuel residing in the vortex chamber is continuing swirling and upon opening of the metering orifice such swirling fluid is immediately ejected therefrom. Passages 170 and 176 need not be used together.

In each of the above embodiments of the invention a substantial pressure differential exists across the metering orifice 134, and as the fuel exits therefrom it is finely atomized. The spray pattern of the fuel is influenced somewhat by the L/D ratio of the metering orifice and may be varied as the application desires.

To facilitate securement to the walls of the engine's cylinder, the injector 8 may include an annular groove 220 and an O-ring 222 therein. Further, to control fuel leakage between the various mating parts of the injector 8, various other O-rings may be used. As an example, the insert 100 may include an annular groove 224 and O-ring 226. In addition, O-rings 230 and 232 may be provided between the insert 100 and the end cap 128 and the valve seat 130 and the end cap 128.

FIGURE 7 illustrates another embodiment of the invention which provides for the continue flow of fuel within the vortex chamber 136. In this embodiment the passages 56 surrounding the stator 70 have been removed. This can be achieved by using a closely fitting cylindrical bobbin 52. An additional flow passage 240 is provided to communicate the annulus 64 with the passages 36 formed within the body 10. A seal 242 is provided to prohibit fuel from flowing from passage 240 into the solenoid assembly 50. The rod 80 and armature 74 are provide with an axial passage 244. The passage 244 does not extend throughout the entire length of the rod 80 but terminates at a cross-hole 246 immediately above the spherical valve surface 84. In this manner the cross-hole 246 is positioned as close as possible to the bottom of the swirl chamber 136. The armature 70 and cap 68 is also provided with an axial passage 248 which terminates at a fitting 250 which is communicated by a

appropriate tubing to drain 172. When the injector 8 is closed fuel flows from annulus 64 through passages 240, 36 and 120 into the swirl chamber 136 wherein the fuel is permitted to swirl and achieve a maximum swirl rate before it is returned to drain through the passages 244, 246 and 248. When the coil 60 is activated the armature 74 is moved toward the stator 70. By virtue of the misaligned of passages 244 and 248 the upward movement of the armature 74 seals passages 244 and 248 terminating communication therethrough. As the rod 80 is withdrawn from the valve seat 130 fuel is ejected therefrom. In this manner upon the opening of the injector the fuel proximate the metering orifice 134 will have already achieved a substantial rotational velocity and exits therefrom immediately forming the conical spray pattern.

Claims

1. A high pressure vortex fuel injector comprising a hollow housing or body (10) including a plurality of passages (36, 56, 64, 120) at least one of which is adapted to receive fuel through an inlet (38);
 - a valve seat (130) secured to said housing (10), including a metering orifice (134), and a first conically shaped surface (132) disposed directly upstream of said metering orifice;
 - means (50) for moving a piston (80) relative to said valve seat (130) to open and close the metering orifice;
 - characterized by means (112) upstream of said metering orifice including a piston guide (100) comprising a second conically shaped surface fixedly spaced from said first conically shaped surface for forming a swirl or vortex chamber (136) in cooperation with said first conically shaped surface (132) and
 - a plurality of obliquely oriented straight passages (120) extending through said piston guide (100) and said second conically shaped surface and oriented at oblique angles relative to the first conically shaped surface (132) of the valve seat such that fuel exiting said passages directly impacts on said first conically shaped surface tangentially and is caused to flow within said swirl chamber in a downward spiral manner towards said metering orifice such that upon removal of said piston from said valve seat, fuel flows out from said metering orifice (134) in a conical spiral manner.
2. A high pressure vortex fuel injector as defined in Claim 1 wherein said piston is relatively loosely received within said first passage (108) such that upon removal of the piston from said valve seat (130), an axial component of the

spray pattern is formed interior to the spiral or vortex components of flow.

Patentansprüche

1. Kraftstoff-Hochdruck-Dralleinspritzvorrichtung mit einem hohlen Gehäuse bzw. Körper (10), der mehrere Kanäle (36, 56, 64, 120) aufweist, von denen mindestens einer zur Aufnahme von Kraftstoff durch einen Auslaß (38) dient;
 - einem am Gehäuse (10) befestigten Ventilsitz (130) mit einer Dosieröffnung (134) und einer ersten konisch geformten Fläche (132), die unmittelbar stromauf der Dosieröffnung angeordnet ist;
 - Mitteln (50) zum Bewegen eines Kolbens (80) relativ zu dem Ventilsitz (130), um die Dosieröffnung zu öffnen und zu schließen;
 - gekennzeichnet durch Mittel (112) stromauf der Dosieröffnung in Form einer Kolbenführung (100) mit einer zweiten konisch geformten Fläche, die einen festen Abstand von der ersten konisch geformten Fläche hat, um eine Wirbel- bzw. Drallkammer (136) in Zusammenarbeit mit der ersten konisch geformten Fläche (132) zu bilden, und
 - mehrere schräg liegende, gerade Kanäle (120), die sich durch die Kolbenführung (100) und die zweite konisch geformte Fläche erstrecken und unter schrägen Winkeln relativ zu der ersten konisch geformten Fläche (132) des Ventilsitzes so ausgerichtet sind, daß aus den Kanälen austretender Kraftstoff tangential unmittelbar auf die erste konisch geformte Fläche auftrifft und veranlaßt wird, innerhalb der Wirbelkammer in einer Abwärtsspirale zu der Dosieröffnung zu strömen, so daß nach Abheben des Kolbens vom Ventilsitz Kraftstoff in einer konischen Spirale aus der Dosieröffnung (134) ausströmt.
2. Kraftstoff-Hochdruck-Dralleinspritzvorrichtung nach Anspruch 1, bei der der Kolben relativ lose in dem ersten Kanal (108) so angeordnet ist, daß nach Abheben des Kolbens vom Ventilsitz (130) eine axiale Komponente des Sprühmusters innerhalb der spiral- bzw. drallförmigen Strömungskomponenten gebildet wird.

Revendications

1. Un injecteur de carburant à tourbillon à haute pression, comprenant une enveloppe ou un corps creux (10) qui comporte un ensemble de passages (36, 56, 64, 120) dont l'un au moins est conçu pour recevoir du carburant traversant une entrée (38);

un siège de soupape (130) fixé au corps (10), comprenant un orifice de dosage (134), et une première surface de forme conique (132) disposée directement en amont de l'orifice de dosage;

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des moyens (50) destinés à déplacer un piston (80) par rapport au siège de soupape (130), pour ouvrir et fermer l'orifice de dosage;

caractérisé par des moyens (112) situés en amont de l'orifice de dosage, comprenant un guide de piston (100) qui comporte une seconde surface de forme conique, espacée de manière fixe de la première surface de forme conique, pour former une chambre de tourbillonnement (136), en association avec la première surface de forme conique (132), et

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un ensemble de passages rectilignes (120) orientés de façon oblique, s'étendant entre le guide de piston (100) et la seconde surface de forme conique, et orientés dans des directions obliques par rapport à la première surface de forme conique (132) du siège de soupape, de façon que le carburant qui sort de ces passages soit directement projeté sur la première surface de forme conique, dans une direction tangentielle, et s'écoule dans la chambre de tourbillonnement en suivant une trajectoire en spirale descendante en direction de l'orifice de dosage, pour qu'au moment où le piston est retiré du siège de soupape, le carburant s'écoule vers l'extérieur à partir de l'orifice de dosage (134) en suivant une trajectoire en spirale conique.

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2. Un injecteur de carburant à tourbillon à haute pression selon la revendication 1, dans lequel le piston est logé de manière relativement lâche dans le premier passage (108), de façon que lorsque le piston est retiré du siège de soupape (130), une composante axiale de la configuration de pulvérisation se forme à l'intérieur des composantes d'écoulement en spirale ou en tourbillon.

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FIG.2

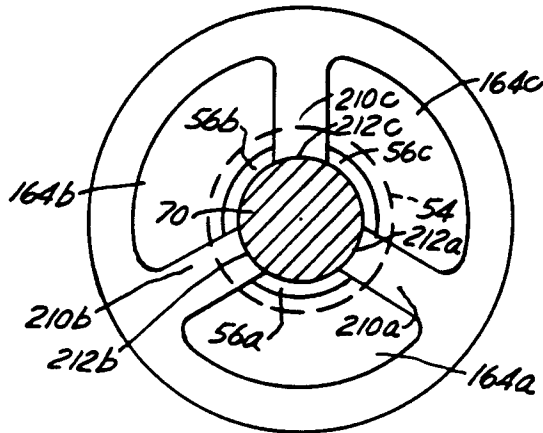


FIG.3

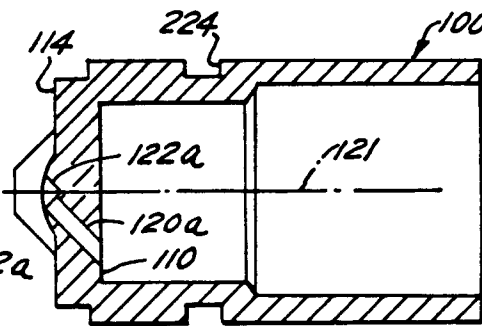
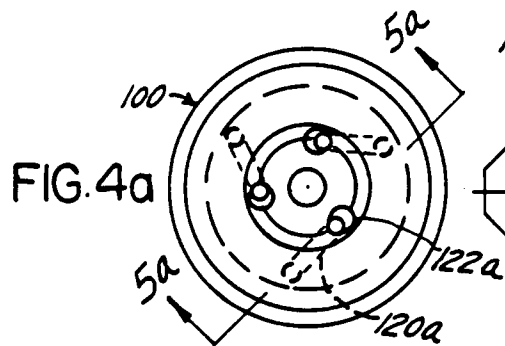
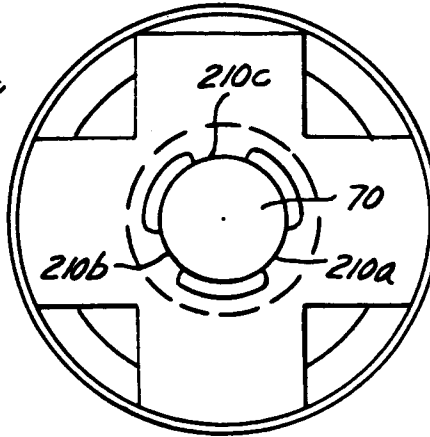


FIG.5a

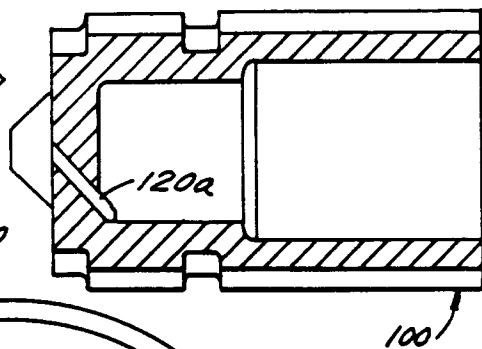
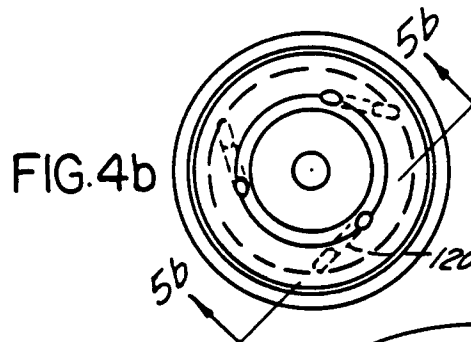


FIG.5b

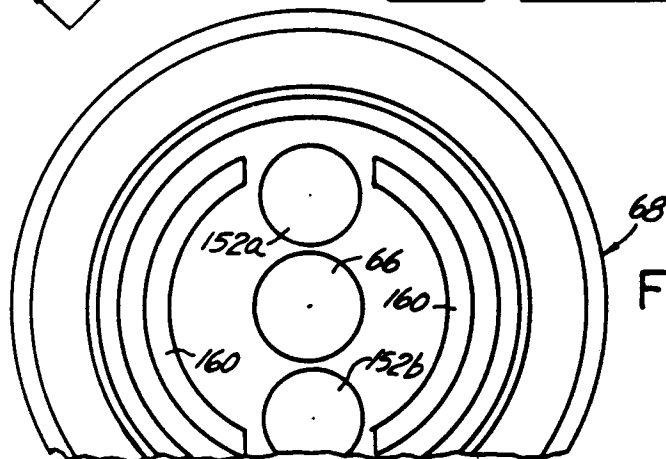


FIG.6

FIG. 7

